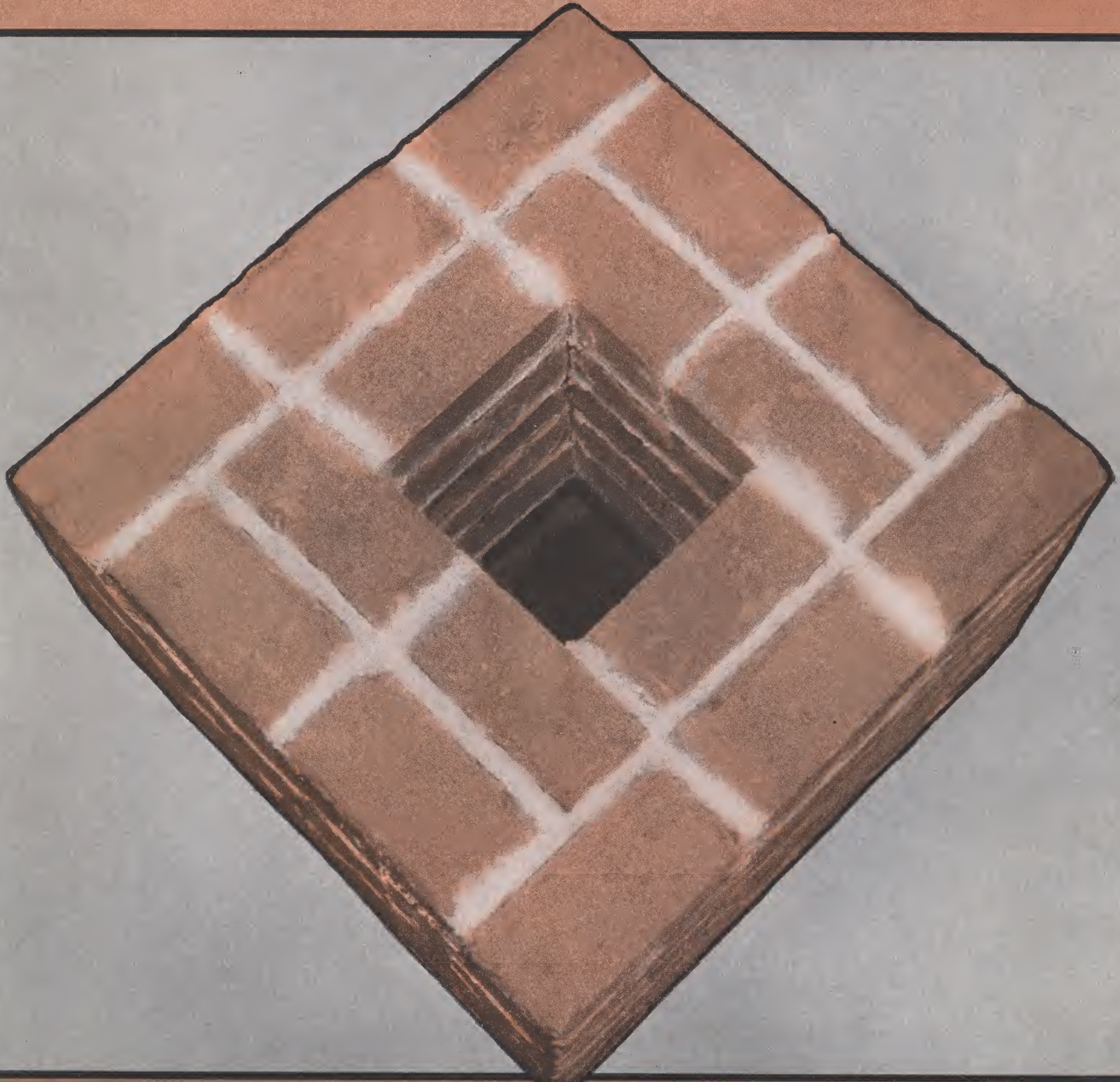
SPECIFICATIONS

RECOMMENDED TO SECURE

DRY BRICK WALLS



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FOREWORD

OVER the past 20 years a great deal of careful research has been carried on to determine how water can be prevented from passing through brick walls. Significant facts have been determined and successful methods have been demonstrated. This information is available to anyone who will study the reports of this research work. However, these reports are so scattered and so technical that the facts they present, though really very simple, are still not generally known in the building industry.

The purpose of this paper is to set forth and explain the significant facts secured in this research and, based on these facts, to recommend certain precautions which should be included in the architect's specifications. All these precautions should be enforced, in order to secure dry brick walls.

This paper covers only the proper use of brick and mortar. No attempt is made to discuss such important details of design as flashing and spandrel waterproofing — lintels designed to shed the water out of rather than into the wall — protruding ledges of brick or stone — provision against expansion, contraction, and deflection of floors and roof slabs, beams and trusses — etc.

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John H. Mallon, *Vice President*
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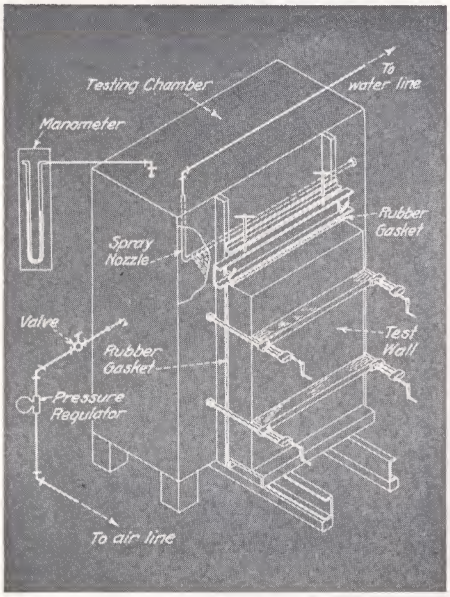
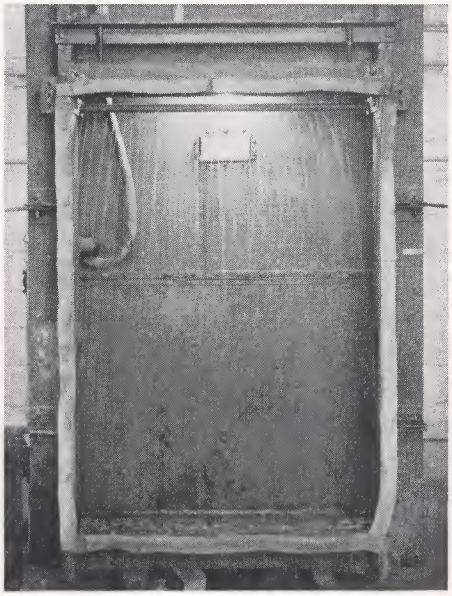
THE CAUSES AND PREVENTION OF LEAKY BRICK WALLS HAVE BEEN STUDIED FOR MANY YEARS BY OUTSTANDING RESEARCH AUTHORITIES

During the past twenty years, a great amount of intensive investigation has been done to determine how water can be prevented from passing through brick walls. This research has included a project by the National Bureau of Standards, in which more than 400 brick walls were erected and tested for more than five years—also a project in Pittsburgh, in which more than 300 brick panels were erected and studied for two years, by Dr. F. O. Anderegg and a committee of fifteen architects, contractors and masons.

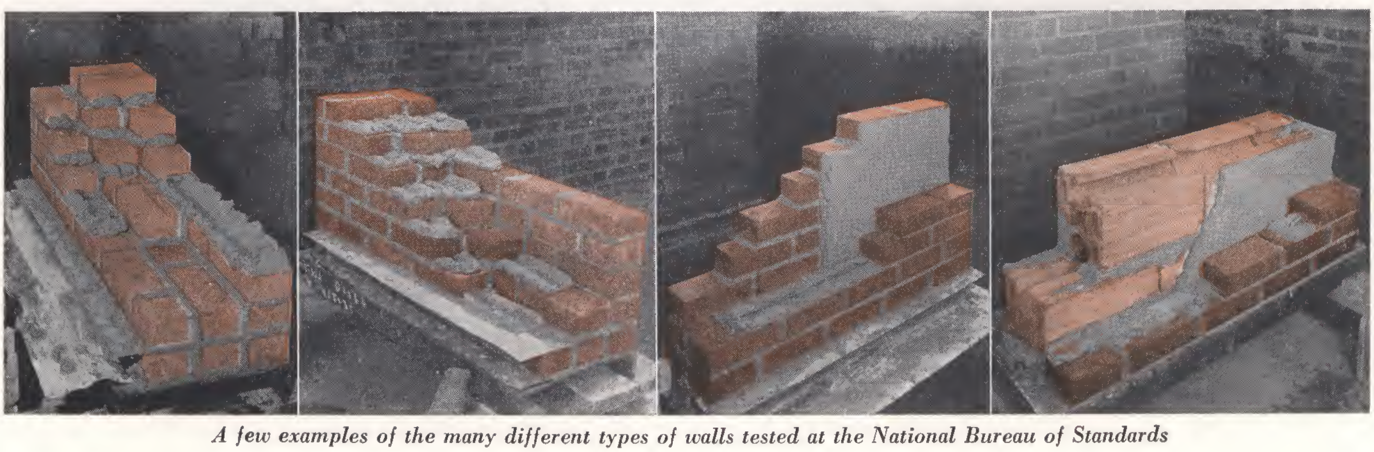
The photographs immediately below show a water-permeability test chamber used in testing walls at the National Bureau of Standards. With this equipment, walls were tested under conditions resembling exposure to a strong wind and heavy rains. Water was applied by means of a spray at the top of the wall, causing a continuous film of water on the exposed face of the wall. The effect of a strong wind was simulated by maintaining an air-pressure of 10 pounds per square foot on the exposed face of the wall.



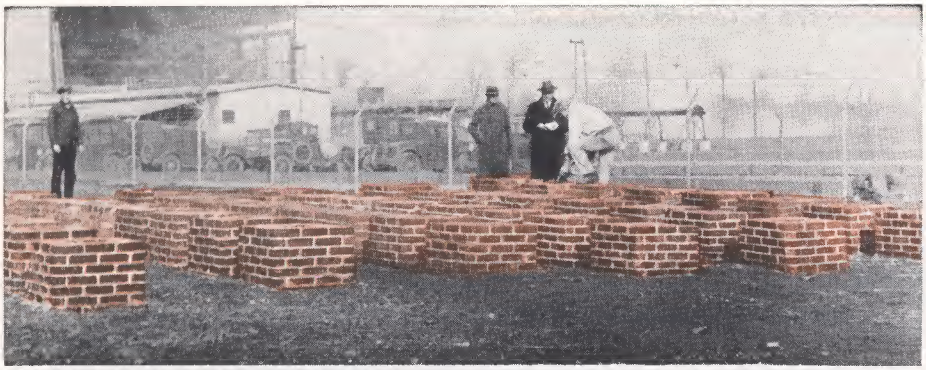
Isometric projection of testing equipment


Test chamber without wall


Test chamber with wall in place


A few examples of the many different types of walls tested at the National Bureau of Standards

Above and Below: Scenes showing some of the 300 brick panels erected and studied in Pittsburgh



Brick reservoirs were used for tests at Louisville Cement Co., also at Alton Brick Co.

Close-up of a reservoir

Panels tested at the University of Kentucky

Panels tested at the Missouri Portland Cement Company

TWENTY YEARS OF RESEARCH HAVE

Water can be made to pass through masonry units, also to pass through mortar, by maintaining a sufficient head of water, or by exposure to a sufficient amount of water over a long period of time.

But in the case of the great majority of brick walls which leak, water does not go through the masonry units or through the mortar. It works its way through cracks or channels between the masonry units and the mortar.

* * * *

The cracks which you see in brickwork are usually due to one of the two following causes:

(1) Sometimes a good bond is not secured between the brick and the mortar at the time the brick is laid, because the brick on which the mortar is spread withdraws so much water from the mortar that the mortar is sucked dry before the next brick comes into contact with it. Brick will not bond properly unless the mortar is still soft and plastic. (See page 7)

(a) When placed on absorbent brick, a mortar with high water-retaining capacity will stay soft and plastic longer than a mortar with low water-retaining capacity.

(b) If the bricks' rate of absorption is too high at the time they are laid, they will suck the water out of the mortar too fast, even though the mortar has high water-retaining capacity.

To insure a good bond, absorbent brick must be thoroughly wet and not allowed to dry out before they are placed in the wall.

(c) A good bond between brick and mortar depends more upon the suction of the brick than it does upon the mortar materials.

. . . AND BECAUSE OF THESE FACTS, THE FOLLOWING

Dry walls will be secured whenever the

(1) Mortar shall be mixed and kept tempered on the boards, so it will at all times contain as much water as it is able to carry. (See page 8)

(2) The mortar shall have high water-retaining capacity and plasticity.

Mortar of the materials and proportions used on the job, when mixed and tested in accordance with Section 30 of A.S.T.M. Specification for Masonry Cement, Designation: C91-51, shall have a flow after suction greater than 70% of the flow immediately after mixing.

The plasticity of the mortar shall be thoroughly satisfactory to the mason. (See page 8)

(3) The brick shall have a low rate of suction at the time they are placed in the wall. To secure this low rate of suction, when absorbent brick are used, they shall be thoroughly wetted and not allowed to dry out. The suction of the brick shall be so reduced by wetting that specimens of brick, taken from the scaffold, shall not gain more than 20 grams (7/10 of an ounce) in weight, when placed in ⅛″ to ¼″ of water, for one minute. (See page 9)

ESTABLISHED THESE FACTS . . . .

(2) Sometimes immediately after the brick is laid, the bond is broken by the bricklayer in his attempt to get perfect alignment. If he changes the position of the brick in any way, after the mortar has already congealed, he will break the bond. (See page 7)

Some cracks, formed in this way, are inevitable on any job.

*   *   *   *

The amount of water which will enter cracks in the face of the wall can be reduced, if all joints on the exterior face of the wall are tooled to give a concave finish. This helps seal the cracks between the brick and the mortar.

*   *   *   *

Even if the mortar has high water-retaining capacity, the brick have been wetted, and the joints have been tooled, some water will inevitably penetrate the face of the wall. Therefore the following precautions should be taken to prevent it from reaching the back of the wall:

All head joints and bed joints should be filled solid with mortar. Voids or channels in the mortar joints provide an easy passage for any water which has penetrated through cracks in the face of the wall.

The face brick should be backplastered before the back-up units are laid. This provides an effective barrier to any water which may find its way through the outside 4″ of the wall.

SPECIFICATIONS ARE RECOMMENDED

following precautions are specified and enforced

(4) All head joints and bed joints on the exterior face of the wall shall be tooled to give a concave finish. This shall be done with a round tool slightly larger than the joint, before the mortar hardens, and with sufficient force to press the mortar tight against the brick on both sides of the joint. (See page 12)

(5) All head joints and bed joints in both face brick and back-up work shall be completely filled with mortar. (See pages 10 and 11)

(6) Before the back-up units are laid, the face brick shall be backplastered with mortar $\frac{3}{8}$″ thick, or of sufficient thickness to insure complete coverage between the header courses. If the back-up units are laid first, the front of the back-up units shall be plastered, before the face brick are laid. (See page 13)

WATER PENETRATES THROUGH CRACKS AND OPENINGS BETWEEN THE BRICK AND MORTAR

When a masonry wall leaks, water almost never passes through the masonry units or through the mortar. It works its way through cracks* or channels between the masonry units and the mortar. This is the unanimous opinion of all who have made a careful study of the leaky brick wall problem.

Newman (1) says, "In the hundreds of leaky buildings we have had occasion to inspect, not one has shown signs of running water due to the absorption of masonry units."

Lent (2) says, "Open or partially filled mortar joints permit water to penetrate the outer course of brick."

Palmer (3) says, "Water penetrates through brick masonry chiefly through cracks and openings *between* bricks and mortar rather than through these materials themselves."

Anderegg (4) says, "Most of the leakage occurs between the mortar and the brick."

Mallon (5), Anderegg (6), and McBurney (7), by the use of dye, traced the passage of water between the brick and the mortar.

**These cracks are not due to "shrinkage" of mortar. Data obtained during an extensive study at the Bureau of Standards indicate that "shrinkage" is not damaging to the bond between the mortar and brick.*

The maximum shrinkage which could occur in a mortar joint between absorbent brick is so small that it could not cause a crack visible to the human eye. "Shrinkage" cannot account for leaks in a brick wall.

Palmer (8) says, "When the extent of bond is practically complete, the results do not indicate an appreciable weakening of the bond through shrinkage of mortar during early hardening.

"There is no evidence that volume changes in mortar subsequent to hardening destroyed or weakened the bond either in vertical or horizontal joints, when the extent of bond is good."

McBurney (7) says, "Such openings are especially noticeable on struck joints and have been mistaken by inexperienced observers for shrinkage cracks."

In his discussion of McBurney's paper (7) Anderegg says, "I agree with the authors that when certain people talk about 'shrinkage cracking' they are basing their estimate on incorrect observation."

When joints are cut flush with the brick, cracks are immediately apparent between the brick and the mortar at the surface of the wall. These cracks do not extend back through the entire width of the brick. They go back only a fraction of an inch, and are not deep enough to cause leaks. Such cracks are not due to shrinkage. The pictures below explain how they occur.

When the bricklayer taps the brick down to the line, the mortar in the bed joint oozes out, and hangs down over the wall, pulling away from the edge of the brick above.

If this excess mortar is cut off with a sideward stroke, the mortar is not pushed up against the edge of the brick above, and a surface crack remains on top of the joint.

If the bed joint is cut off with an upward stroke, the trowel pulls the mortar away from the edge of the brick below, and a surface crack is opened below the bed joint.

If the head joint is cut off with an upward stroke of the trowel, no surface crack appears.

If a sideward trowel stroke is used to cut off the head joint, the trowel pulls the mortar away from the brick and forms a surface crack on the side from which the stroke was made.

MOST CRACKS THROUGH WHICH WATER CAN PASS ARE DUE TO ONE OF TWO CAUSES:

(1) A good bond was not secured at the time the brick was laid

Failure to secure a good initial bond between the brick and the mortar is usually due to the fact that the brick on which the mortar is spread withdraws so much water from the mortar that it is sucked dry before the next brick comes into contact with the mortar.

Here the brick on which the mortar was spread withdrew so much water from the mortar that the mortar dried out before the next brick came into contact with it

Brick will not bond properly with mortar unless the mortar is still soft and plastic.

Here the mortar was still soft and plastic when the next brick was placed

(2) The bond was broken after the brick was laid

Sometimes shortly after the brick is first laid, but after the mortar has stiffened, the bricklayer changes slightly the position of the brick in his attempt to get perfect alignment.

If the mortar has already congealed, *any* movement of the brick will break the bond.

He may lift the brick from the mortar bed and reset it

He may shift the brick to even out the head joints

He may hammer down the back edge of the brick to bring it down level with the line, and thereby tilt up the front edge

He may hammer a brick back into line after a course has been laid on top of it.

He may tap a corner brick back to make it plumb with the face of the wall

HOW LEAKS CAN BE PREVENTED

MORTAR SHOULD NOT BE ALLOWED TO DRY OUT ON THE BOARD

Mortar should be mixed and kept tempered on the board, so the mortar will contain as much water as it is able to carry, whenever the bricklayer picks up a trowel full of mortar.


Mortar on the boards should be kept well tempered with water

Data obtained by M. O. Withey (9), of the University of Wisconsin, indicate that the most complete contact of mortar with brick, and joints of highest tensile strength, are likely to be obtained if the mortar is as wet as may be used conveniently. Anderegg (6) says, "The wetness of the mortar is the most important single factor in securing complete contact with an absorbent unit."

THE MORTAR SHOULD HAVE HIGH WATER-RETAINING CAPACITY

Water-retaining capacity is the ability of a mortar to retain its moisture, and hence its plasticity, when spread out on porous brick.

When placed on absorbent brick, a mortar with high water-retaining capacity will stay soft and plastic longer than mortar with low water-retaining capacity.

If the mortar does not have high water-retaining capacity, it is too quickly sucked dry by the brick; the mortar stiffens too soon, the brick cannot be properly bedded, and a good bond cannot be obtained.

For all practical purposes, the water-retaining capacity of a mortar can be judged by its plasticity. Mortars which have excellent plasticity have high water-retaining capacity. Mortars which have poor plasticity have low water-retaining capacity.

Palmer (10) says, "A poorly workable mortar invariably has low water-retaining capacity."


If the mortar does not have high water-retaining capacity, the mortar stiffens too soon and a good bond cannot be obtained

Palmer (8) says, "The data indicate that the water retaining capacity of mortars and absorption rate of bricks were of primary importance in obtaining a good bond." Parsons (11), says, "The essential quality of mortar was found to be workability and water retentivity. Workable mortars which stiffened slowly when in contact with absorptive units were desired by the masons, and more satisfactory walls were obtained with them than with mortars which stiffened rapidly." Anderegg (12) says, "Trouble is usually due to the presence of depressions in the mortar surface in contact with the brick, caused apparently by incomplete wetting of the brick by the mortar, or by too rapid moisture removal while the mortar is still plastic, or both."

THE BRICK SHOULD HAVE A LOW RATE OF ABSORPTION AT THE TIME THEY ARE LAID

A good bond between brick and mortar depends more upon the suction of the brick than it does upon the mortar materials.

If at the time the brick are laid, their rate of absorption is too high, they will suck the water out of the mortar too fast, even though the mortar has high water-retaining capacity.

In so far as the bond is concerned, best results are secured with brick having a low rate of absorption at the time they are laid.

To secure a low rate of absorption it is necessary to wet absorbent brick. Except for impervious types, all brick should be thoroughly wetted to reduce their suction, and not allowed to dry out before they are placed in the wall.

If brick taken from the scaffold will gain more than 20 grams (7/10 of an ounce) in weight when placed flat in 1/8″ to 1/4″ of water for one minute, their rate of absorption is too high and must be reduced by wetting or re-wetting.

McBurney (7) says, "It is well recognized that the initial rate of absorption of clay and shale building bricks is one of the important factors affecting the water permeability of brick-mortar combinations in masonry.

"Differences in bricks had much more effect on permeability than differences in mortar."

Anderegg (12) says, "The rate at which moisture is removed from the mortar by the brick has a marked influence on the bond strength and water-tightness of the wall."

Palmer (13) says, "The data indicate that although the maximum rate of water transmission varied both with the brick and mortar used, it was affected relatively more by the brick than by the mortar.

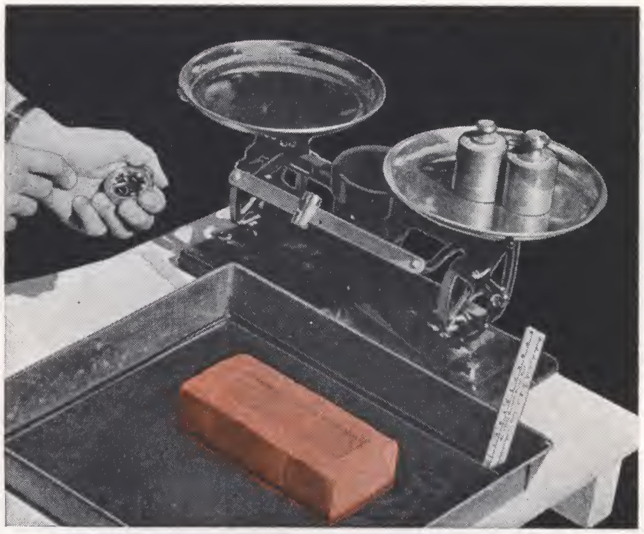
"The test results show that, irrespective of the properties of the mortar used, the leakage of the specimens was less when bricks of moderate or high suction were wetted before laying than when they were set dry."

Parsons (11) says, "With bricks having too high a rate of absorption, there is a tendency for the mortar to lose water rapidly and to become too stiff to form a complete bond with the brick. Although the rate of stiffening of mortar when in contact with absorptive units is minimized by the use of mortars of easy working properties and high water retaining capacity, strong and watertight joints were not obtained with mortars which were best in these respects unless bricks having high rates of absorption were wetted before laying."

Fishburn (14) says, "The great importance of thoroughly wetting brick before they are laid should not be minimized. If the brick suction is not determined, care should be taken to have all brick well wetted and, if possible, nearly saturated at the time of laying. Little difficulty should be experienced in laying brick that are nearly saturated so long as no water is visible on the surfaces of the brick. This may involve frequent wetting, especially for high absorptive brick laid in hot, dry weather.

"Walls having a satisfactory resistance to rain penetration may be built of bricks, regardless of the method of forming or manufacture of the bricks, provided the absorption of the bricks at the time of laying is kept within the proper limit by preliminary wetting."

Anderegg (12) says, "Bricks of higher absorption rate should have their excess sucking power diminished by wetting."



Brick should be taken from the scaffold and checked for rate of absorption

This does not mean, however, that impervious brick or brick with low absorption should be specified. A considerable amount of absorption is a very desirable property of brick in the finished wall. This is particularly true of back-up units. If the wall is built entirely with units of low absorption, any water that enters through cracks is apt to go right on through the wall. But if the back-up units have a certain amount of absorption, these softer units, acting somewhat like a sponge, will absorb and hold back the water. Later, when the sun hits the face of the wall, the moisture will evaporate out again, almost as though the wall were breathing.

Fishburn (14) says, "High absorptive brick provided a time-factor of safety that walls built of the low-absorptive brick did not possess."

Palmer (13) says, "When the joints are not completely filled with mortar, water is more apt to penetrate into the interior of the building if the bricks are very impervious than would be the case were the bricks porous."

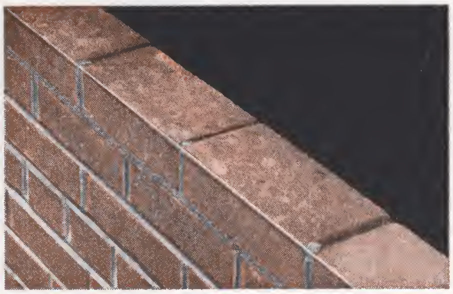
McBurney (15) says, "The volume of water capable of being absorbed is an important factor in delaying striking through of moisture."

Palmer (13) says, "Brick No. 5, smooth and very impervious, is of special interest since it is a type of unit that has been widely associated with leaking buildings. Since it is incapable of absorbing any appreciable amount of water, it is obvious that water entering through joints left unfilled by the mason in walls of this brick must either be absorbed by the more porous back-up materials, descend between the back of the wall and the furring, or else penetrate into the interior of the building."

HEAD JOINTS AND BED JOINTS SHOULD BE FILLED SOLID

If the joints are not filled solid with mortar, voids and channels are left, which provide easy passage for any water which has penetrated through cracks in the face of the wall.

When a dab of mortar is spotted on one corner of the brick,



the mortar does not fill the head joint

Only part of the head joint is filled with mortar

Slushing does not properly fill the voids in the head joints

When mortar is spotted on only one corner of the brick, slushing seldom fills the voids

Even when mortar is spotted on both corners, slushing will not always fill the voids

Even when mortar is spotted on both corners of the header brick, there is not enough mortar in the joint

Slushing will seldom fill the voids

When hollow back-up units are used, the head joints in the interior of the wall, next to the face brick, should not be left open

If all joints are not full of mortar, back-up units give little protection

WITH MORTAR

All head joints and bed joints in both face brick and back-up work should be completely filled with mortar. This is the most important precaution which can be taken to secure a dry wall.

A thick bed of mortar should be spread on the wall

The furrow in the mortar should be shallow, not deep

Then the excess mortar will fill the furrow and insure full bed joints

Plenty of mortar should be thrown on the end of the brick to be placed

The brick should then be pushed into place

so that the mortar oozes out at the top of the head joint

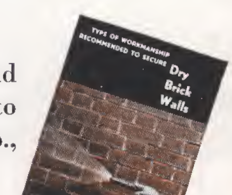
Mortar should be spread over the entire side of the header brick before it is placed

The brick should be shoved into place so that mortar oozes out at the top of the joint

This completely fills the joint

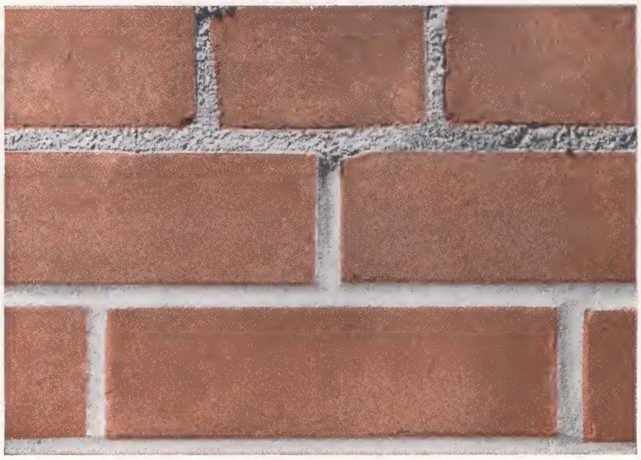
Newman (16) says, "Where workmanship has been the cause of leaking walls, it has been due in most cases to lack of sufficient mortar in the end joints." Coe (17) says, "The factor most important to moisture proof brickwork—the good workmanship necessary to completely fill all joints with mortar." Parsons (18) says, "The quality of the workmanship had a far greater effect than any other visible factor in the study." Anderegg (12) says, "Upon the bricklayer's workmanship, more than upon any other single factor, rests the responsibility for the integrity of the wall." Fishburn (14) says, "Workmanship was found to be the most important factor affecting the permeability of masonry walls."

The type of workmanship which should be specified to secure dry brick walls is explained and illustrated in the manual shown on the right. A copy will be sent free, without obligation, to any architect, contractor, bricklayer, or dealer who requests it. Write the Louisville Cement Co., Louisville, Kentucky, for this "Workmanship Book".



JOINTS SHOULD BE TOOLED TO GIVE A CONCAVE FINISH

The amount of water which will enter cracks in the face of the wall can be reduced, if all joints on the exterior face of the wall are tooled to give a concave finish. Such tooling helps seal the entrance to the cracks between the brick and the mortar.



Concave tooling helps seal the entrance to any cracks between the brick and the mortar

Stanley Newman (16) says, "The joints that afford the best protection are those of the weathered and concave type. These not only present an excellent surface for the shedding of water, but require for their formation an amount of pressure sufficient to compress the mortar and create a firm bond between the mortar and the brick at the face of the wall, thereby reducing the probability of hidden cavities."

The Committee on Materials and Methods of the Boston Society of Architects (19) says, "The Committee recommends that too wide a joint be avoided and that all joints should be ruled with a jointing tool. The most weathertight type of joint seems to be formed by a pipe jointer making a slightly concave surface."

Anderegg (12) says, "A careful tooling of the joint is sometimes literally the final touch needed to make the joint watertight. Cases have been known where identical conditions of bricklaying prevailed in the same building, but the joints were part scored and part pointed with a round tool. The former leaked, while the latter did not, in spite of similar exposure."

Tooling should be done with a round tool slightly larger than the joint, before the mortar hardens, and with sufficient force to press the mortar tight against the brick on both sides of the mortar joint.

Before the mortar hardens, joints should be tooled with sufficient force to press the mortar tight against the brick on both sides of the mortar joint

Concave joints should always be used for face brick, unless the architecture requires some other type of finish. No other type of joint provides as much protection against the entrance of water.

A weathered joint does not always pack the mortar against the top brick thoroughly

A struck joint leaves a shelf on which water collects

A raked joint leaves a bad shelf and often contains too little mortar

THE FACE BRICK SHOULD BE BACK-PLASTERED

Before the back-up units are laid, the face brick should be backplastered with mortar 3/8" thick, or of sufficient thickness to insure complete coverage between the header courses. If the back-up units are laid first, the front of the back-up units should be plastered, before the face brick are laid.

This provides an effective barrier to any water which may find its way through the outside 4 inches of the wall. This is especially true if a waterproofed mortar is used.

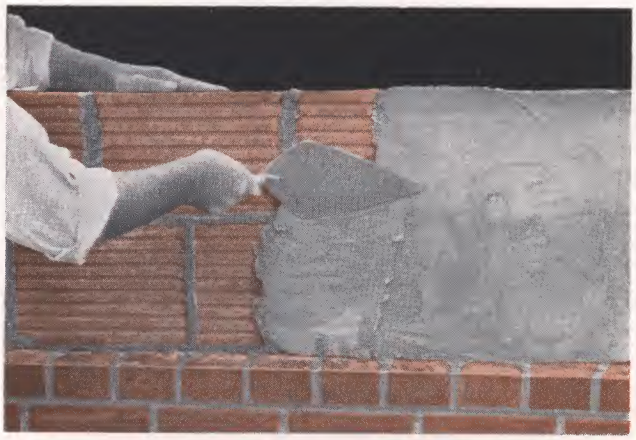
The Committee on Materials and Methods of the Boston Society of Architects (19) says, "The Committee recommends that the back of all face brick be parged with mortar of the same mix as that in which the brick is laid, as the wall progresses in height; that is, after five or six courses of face brick are laid, parge the back of this brick before placing the backing. This work should be thoroughly done so that no voids may be left which may permit the passage of moisture into the backing. This will also tend to fill up the end joints of masonry work."

Parsons (18) says, "The plastering of mortar on the back of 4-inch walls resulted in masonry of high resistance to rain penetration."

Bevier (20) says, "Before the tile are set, the back side of the face brick should be entirely covered with enough mortar to fill the space between the brick and the tile."

The Technical News Bulletin of the National Bureau of Standards (21) says, "The application of a pargeting of mortar on the back of the facing wythe helped to make walls more resistant to moisture penetration."

The face brick should be back-plastered with 3/8" of mortar, before the back-up units are laid



If the back-up units are laid first, the front of the back-up units should be plastered

SLUSHING DOES NOT TAKE THE PLACE OF BACK-PLASTERING

Frequently specifications are written providing either that the face brick should be back-plastered or that the space between the face brick and the back-up units should be slushed full of mortar.

Slushing does not give the same protection against the penetration of water that back-plastering gives.

It is almost impossible by slushing to completely fill the space between the face brick and the back-up work. Frequently the mortar is caught and held before it reaches the bottom of the narrow crevass, leaving openings between the face brick and the back-up units.

Even when this space is filled, there is no way to compact the mortar against the face brick. The mortar does not bond with the brick over its entire surface. Channels are left between the mortar and the brick, through which water can trickle down behind the face brick until it finds a header or a floor along which it can travel to reach the back of the wall.

Slushing does not completely fill the space between the face brick and the back-up work

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THE AMERICAN INSTITUTE OF ARCHITECTS
THE OCTAGON, 1741 NEW YORK AVENUE, N.W., WASHINGTON 6, D. C.

December 21, 1950

Mr. John H. Mallon, Vice President
Louisville Cement Company, Inc.
Speed Building
Louisville, Kentucky

Dear Mr. Mallon:

The importance of sound masonry construction, from the standpoint of the stability of the structure, as well as the avoidance of the results of moisture penetration, and excessive maintenance costs, cannot be over emphasized.

In the publication, some five years ago, of "TYPE OF WORKMANSHIP RECOMMENDED TO SECURE DRY BRICK WALLS," you made a worthwhile contribution to sound construction of informative value to architects and builders.

Your new publication, "SPECIFICATIONS RECOMMENDED TO SECURE DRY BRICK WALLS," makes available not only the specification requirements for sound, moisture resistant brick masonry but illustrates the techniques of brick laying necessary to insure these results.

In so adequately presenting the results of twenty years of painstaking research you have again directed attention to the fact that sound, moisture resistant brick masonry depends upon those who design and specify the work, the contractors who construct the same, and the craftsmen responsible for its field fabrication.

Sincerely yours,

Theodore Irving Coe

Theodore Irving Coe
Technical Secretary

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